AD NO. ____________________________
DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC-9244

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

OPEN FIELD SCORING RECORD NO. 802

SITE LOCATION:
U.S. ARMY ABERDEEN PROVING GROUND

DEMONSTRATOR:
GEOCENTERS SAIC
7 WELLS AVENUE
NEWTON, MA 02459

TECHNOLOGY TYPE/PLATFORM:
VEHICULAR SIMULTANEOUS EMI AND
MAGNETOMETER SYSTEM (VSEMS)/TOWED

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MD 21005-5059

NOVEMBER 2006

Prepared for:
U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MD 21010-5401

U.S. ARMY DEVELOPMENTAL TEST COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

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CSTE-DTC-AT-SL-E

MEMORANDUM FOR RECORD

SUBJECT: Operations Security (OPSEC) Review of Paper/Presentation

1. The attached record entitled "The Standardized UXO Technology Demonstration Site Open Field Scoring Record #802" dated November 2006 is provided for review for public disclosure in accordance with AR 530-1 as supplemented. The scoring record is proposed for public release via the internet.

2. I, the undersigned, am aware of the intelligence interest in open source publications and in the subject matter of the information I have reviewed for intelligence purposes. I certify that I have sufficient technical expertise in the subject matter of this report and that, to the best of my knowledge, the net benefit of this public release outweighs the potential damage to the essential secrecy of all related ATC, DTC, ATEC, Army or other DOD programs of which I am aware.

Michael Karwatka		November 2006
NAME (Printed)	SIGNATURE	DATE

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Program Mgr/Customer (If not ATC owned technology)	Patrick McDonnell		9 Nov 06
Core Director	John Kopczynski		22 Nov 06
Core OPSEC Tech POC	William Burch		31 OCT 06
ATC OPSEC Officer/ Security Manager	William Murr		Rec'd 29 Nov 06 29 Nov 06
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Karwatka, Mike; Packer, Bonnie
The Standardized UXO Technology Demonstration Site Scoring Committee

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Commander
U.S. Army Aberdeen Test Center
ATTN: CSTE-DTC-AT-SL-E
Aberdeen Proving Ground, MD 21005-5059

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Commander
U.S. Army Environmental Center
ATTN: SFIM-AEC-ATT
Aberdeen Proving Ground, MD 21005-5401

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14. ABSTRACT
This scoring record documents the efforts of Geocenters SAIC to detect and discriminate inert unexploded ordnance (UXO) utilizing the APG Standardized UXO Technology Demonstration Site Blind Grid. Scoring Records have been coordinated by Mike Karwatka and the Standardized UXO Technology Demonstration Site Scoring Committee. Organizations on the committee include, the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Center, and the U.S. Army Aberdeen Test Center.

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Authors:

Rick Fling
Aberdeen Test and Support Services (ATSS)
Sverdrup Technology, Inc.
U.S. Army Aberdeen Proving Ground (APG)

Christina McClung
Aberdeen Data Services Team (ADST)
Logistics Engineering and Information Technology Company (Log.Sec)
U.S. Army Aberdeen Proving Ground (APG)

Contributors:

Matthew Banta
Aberdeen Test and Support Services (ATSS)
Sverdrup Technology, Inc.
U.S. Army Aberdeen Proving Ground (APG)

Michael Karwatka
Military Environmental Technology Demonstration Center (METDC)
U.S. Army Aberdeen Test Center (ATC)
U.S. Army Aberdeen Proving Ground (APG)

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SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

Technologies under development for the detection and discrimination of munitions and explosives of concern (MEC) – i.e. unexploded ordnance (UXO) and discarded military munitions (DMM) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground (APG), Maryland and U.S. Army Yuma Proving Ground (YPG), Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the U.S. Army Environmental Center (USAEC). The U.S. Army Aberdeen Test Center (ATC) and the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP) and the Army Environmental Quality Technology Program (EQT).

1.2 SCORING OBJECTIVES

The objective in the Standardized UXO Technology Demonstration Site Program is to evaluate the detection and discrimination capabilities of a given technology under various field and soil conditions. Inert munitions and clutter items are positioned in various orientations and depths in the ground.

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under realistic scenarios that vary targets, geology, clutter, topography, and vegetation.

b. To determine cost, time, and manpower requirements to operate the technology.

c. To determine demonstrator's ability to analyze survey data in a timely manner and provide prioritized "Target Lists" with associated confidence levels.

d. To provide independent site management to enable the collection of high quality, ground-truth, geo-referenced data for post-demonstration analysis.

1.2.1 Scoring Methodology

a. The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}), and those that do not correspond to any known item, termed background alarms.

b. The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the blind grid RESPONSE STAGE, the demonstrator provides the scoring committee with a target response from each and every grid square along with a noise level below which target responses are deemed insufficient to warrant further investigation. This list is generated with minimal processing and, since a value is provided for every grid square, will include signals both above and below the system noise level.

c. The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such and to reject clutter. For the blind grid DISCRIMINATION STAGE, the demonstrator provides the scoring committee with the output of the algorithms applied in the discrimination-stage processing for each grid square. The values in this list are prioritized based on the demonstrator's determination that a grid square is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For digital signal processing, priority ranking is based on algorithm output. For other discrimination approaches, priority ranking is based on human (subjective) judgment. The demonstrator also specifies the threshold in the prioritized ranking that provides optimum performance, (i.e. that is expected to retain all detected ordnance and rejects the maximum amount of clutter).

d. The demonstrator is also scored on EFFICIENCY and REJECTION RATIO, which measures the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from non-ordnance items. EFFICIENCY measures the fraction of detected ordnance retained after discrimination, while the REJECTION RATIO measures the fraction of false alarms rejected. Both measures are defined relative to performance at the demonstrator-supplied level below which all responses are considered noise, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

e. Based on configuration of the ground truth at the standardized sites and the defined scoring methodology, there exists the possibility of having anomalies within overlapping halos and/or multiple anomalies within halos. In these cases, the following scoring logic is implemented:

(1) In situations where multiple anomalies exist within a single R_{halo}, the anomaly with the strongest response or highest ranking will be assigned to that particular ground truth item.

(2) For overlapping R_{halo} situations, ordnance has precedence over clutter. The anomaly with the strongest response or highest ranking that is closest to the center of a particular ground truth item gets assigned to that item. Remaining anomalies are retained until all matching is complete.

(3) Anomalies located within any R_{halo} that do not get associated with a particular ground truth item are thrown out and are not considered in the analysis.

f. All scoring factors are generated utilizing the Standardized UXO Probability and Plot Program, version 3.1.1.

1.2.2 Scoring Factors

Factors to be measured and evaluated as part of this demonstration include:

a. Response Stage ROC curves:

(1) Probability of Detection (P_d^{res}).

(2) Probability of False Positive (P_{fp}^{res}).

(3) Background Alarm Rate (BAR^{res}) or Probability of Background Alarm (P_{BA}^{res}).

b. Discrimination Stage ROC curves:

(1) Probability of Detection (P_d^{disc}).

(2) Probability of False Positive (P_{fp}^{disc}).

(3) Background Alarm Rate (BAR^{disc}) or Probability of Background Alarm (P_{BA}^{disc}).

c. Metrics:

(1) Efficiency (E).

(2) False Positive Rejection Rate (R_{fp}).

(3) Background Alarm Rejection Rate (R_{BA}).

d. Other:

(1) Probability of Detection by Size and Depth.

(2) Classification by type (i.e., 20-, 40-, 105-mm, etc.).

(3) Location accuracy.

(4) Equipment setup, calibration time and corresponding man-hour requirements.

(5) Survey time and corresponding man-hour requirements.

(6) Reacquisition/resurvey time and man-hour requirements (if any).

(7) Downtime due to system malfunctions and maintenance requirements.

1.3 STANDARD AND NONSTANDARD INERT ORDNANCE TARGETS

The standard and nonstandard ordnance items emplaced in the test areas are listed in Table 1. Standardized targets are members of a set of specific ordnance items that have identical properties to all other items in the set (caliber, configuration, size, weight, aspect ratio, material, filler, magnetic remanence, and nomenclature). Nonstandard targets are inert ordnance items having properties that differ from those in the set of standardized targets.

TABLE 1. INERT ORDNANCE TARGETS

Standard Type	Nonstandard (NS)
20-mm Projectile M55	20-mm Projectile M55
	20-mm Projectile M97
40-mm Grenades M385	40-mm Grenades M385
40-mm Projectile MKII Bodies	40-mm Projectile M813
BDU-28 Submunition	
BLU-26 Submunition	
M42 Submunition	
57-mm Projectile APC M86	
60-mm Mortar M49A3	60-mm Mortar (JPG)
	60-mm Mortar M49
2.75-inch Rocket M230	2.75-inch Rocket M230
	2.75-inch Rocket XM229
MK 118 ROCKEYE	
81-mm Mortar M374	81-mm Mortar (JPG)
	81-mm Mortar M374
105-mm HEAT Rounds M456	
105-mm Projectile M60	105-mm Projectile M60
155-mm Projectile M483A1	155-mm Projectile M483A
	500-lb Bomb

JPG = Jefferson Proving Ground
HEAT = high-explosive antitank

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

POC: Mr. Rob Siegel
(617) 618-4662

Address: Geocenters SAIC
7 Wells Avenue
Newton, MA 02459

2.1.2 System Description (provided by demonstrator)

The vehicular simultaneous electromagnetic interference (EMI) and magnetometer system (VSEMS) (fig. 1) is a vehicle-towed array that simultaneously collects total field magnetometer (MAG) and electromagnetic (EM) 61 MKII data. Normally these two sensors can't be deployed within about 30 feet of each other because the active nature of the EM61 sensor creates noise on the magnetometers, but VSEMS contains patented-applied-for electronics that interleave the two data streams, monitoring the EM61 sync pulse and waiting until the secondary fields it creates have died down before sampling the magnetometers when the EM61's are quiet. In this way, we concurrently collect high-quality EM61 and magnetometer data in a single survey pass. New to VSEMS for this fielding are a carbon fiber platform designed for survivability and minimizing unregistered sensor motion, improved system timing in the electronics and software designed to time-stamp the sensor updates as accurately as possible, and three Global Positioning System (GPS) receivers on the platform designed to position the sensors as accurately as possible. All of these modifications contribute to the goal of improving the accuracy of each position update from each sensor.

Figure 1. Demonstrator's system, VSEMS dual/towed.

Tow Vehicle	Custom-built aluminum-framed dune buggy with very low magnetic self-signature.
Sensor Platform	Custom-built fiberglass platform, reinforced with marine-grade plywood, with titanium suspension to host both magnetometers and EM61s in low-noise environment. New carbon fiber platform under development.
Magnetometers	Five Geometrics 822A aircraft quality cesium vapor total field magnetometers
Magnetometer Interface	Science Applications International Corporation (SAIC's) custom MAG Period Counter (developed under ESTCP Project No. UX-0208) that interleaves magnetometer data between EM61 pulses. Unique to SAIC and patent applied for.
Magnetometer Sampling Rate	75 Hz interleaved between EM61 pulses.
EM61 Configuration	Five Geonics EM61 MKII's (4 time gates) driving five 1 by 1/2 meter coils arranged with the short axis cross-track for maximum cross-track resolution.
EM61 Sampling Rate	75 Hz internal; 10 Hz serial output.
Sensor Swath	2.5 meters (EM61 coils edge-to-edge).
GPS	Trimble real-time kinematic (RTK)-equipped system for 2 cm accuracy in real time.
GPS-Magnetometer Synchronization	Magnetometers are triggered by GPS 1 PPS signal, guaranteeing acquisition of correctly synchronized data (patented and unique to VSEMS).
Survey Speed	1 to 5 mph on smooth, level, vegetation-free terrain.
Surveys	Nearly 900 acres of real-world UXO and MEC sites.

2.1.3 Data Processing Description (provided by demonstrator)

Most data processing occurs in custom Linux-based software. The software internally converts the GPS data from latitude and longitude into Universal Transverse Mercator (UTM) coordinates. The GPS data were read to determine the spatial extent of the site surveyed. The software then sets up a site (a grid in memory) that wholly contained the surveyed data. The position data were examined and corrected as needed. Automatic correction examines the position data for jumps that were greater than possible for low-speed vehicular data. The heading between updates was determined and the position of the 75 Hz MAG and 10 Hz EM samples were calculated. If large jumps in the position data were encountered (e.g., jumps caused by short term differential dropouts), the operator was asked to examine the data and hand-correct a bad point by forcing it to align with the normal survey line. The corrected navigation data was then saved with the sensor data in a new file.

The MAG data were then notch-filtered to remove the 60 Hz electrical hum that is pervasive around buildings and power lines. The MAG and EM61 data were then (background-leveled). Typically, a median filter is used to determine the background reading for a 5-second window, and then this background is subtracted out. The EM61 data is then latency-corrected by visually inspecting the data and adjusting the latency correction so that portions of anomalies acquired in opposite directions line up. The data were then gridded. A linear inverse distance squared interpolation was used, with an interpolation window of $\pm$ 30 cm. This interpolation window functions in both directions. Interpolation is performed cross-track (between the sensors spaced 1/2 meter apart) as well as along the direction of travel (between the 75 Hz MAG or 10 Hz EM updates).

Target analysis commenced once the interpolated image was displayed. The operator adjusted a zoom-in factor and display scales (e.g. ± 250 gammas) or gray scale highlights (e.g., highlight every reading over 50 gammas as red). Anomaly analysis is accomplished with the operator selecting an area of interest (AOI) around an anomaly. The data high and low values were determined and displayed inside the AOI and were used as a seed, based on the full width at half maximum rule, for the model match. The data inside the AOI was then matched recursively to a magnetic dipole model. The results of the model match provided anomaly location and estimated depth and size. These parameters, along with optional operator comments, are logged into the site target file. This procedure worked well for isolated anomalies. Complex anomalies, caused by clusters of multiple objects or geology, required more expert operator interaction. If the magnetic dipole model failed to converge, or converged on an impossible or unphysical result, the operator could log the location based on the full width at half maximum rule. In this case, no estimate of depth or size could be produced. The operator could also pin-point a target's location with the mouse. Again no depth or size estimates were available for such targets. A sequential number was assigned to each target. For large, complex, extended areas of contamination, an operator could create a perimeter landmark file that logged pin-point locations selected by the operator. MAG and pulsed EM data were analyzed simultaneously by running two copies of the VSEMS workstation software and linking them together so that panning and scrolling in one pans and scrolls in the other, and drawing an area of interest in one draws the same area of interest in the other.

When the operator completed the analysis, the target report was output in a format suitable for importation into other tools such as Excel and Word. The target report contained targets from both the MAG and EM61 data. The coordinates used in the report file were transformed to the required system (e.g. State Grid Plane or UTM).

2.1.4 Data Submission Format

Data were submitted for scoring in accordance with data submission protocols outlined in the Standardized UXO Technology Demonstration Site Handbook. These submitted data are not included in this report in order to protect ground truth information.

2.1.5 Demonstrator Quality Assurance (QA) and Quality Control (QC) (provided by demonstrator)

QC. Base GPS was set up over a known control point. Sensors were warmed up for 5 minutes prior to data collection. An object was passed in front of each sensor and the response on the vehicle computer was examined to verify that each sensor was operating and connected to the correct channel. Prior to coming to the site, cable shake issues and approximate EM61 latency issues were resolved. When required, additional Corps of Engineers - Huntsville Center (CEHNC)-mandated QC static tests, shake tests, and six-line tests were performed on-site.

QA. Geocenters SAIC operators understand geophysics and sensors and know when things are working and when they are not. Numerical outputs from the sensors and the GPS are displayed at all times in the vehicle, and these values were examined at the start and finish of every survey line. A small test set of data on the site was acquired and processed and examined to verify that there would be no surprises. An automated data quality program examines the data and reports out-of-range MAG readings and bad (non-differential) position readings. This gives a quick and convenient benchmark on out-of-range data that may be indicative of navigation or sensor errors. Vehicle data were downloaded at lunch, and the data were examined to ensure that no degradation had occurred since morning. Data were downloaded again at the end of the day. Coordinates of the site and grids were overlaid on the site over data to verify that data were being correctly positioned. All GPS data were examined and hand-corrected when necessary if the radio link between base and rover was interrupted. All sensor data were examined by hand. All magnetometer and EM61 data were background-leveled. Latency-correcting the MAG data was not necessary since Geocenters SAIC's hardware is designed to trigger the magnetometers using the GPS' 1 PPS, which guarantees latency-free data. The EM61 data were latency corrected in an industry-standard fashion, lining up halves of anomalies acquired in opposite direction.

2.1.6 Additional Records

The following record(s) by this vendor can be accessed via the Internet as MicroSoft Word documents at www.uxotestsites.org. The Blind Grid Counterpart to this report is Scoring Record No. 792.

2.2 APG SITE INFORMATION

2.2.1 Location

The APG Standardized Test Site is located within a secured range area of the Aberdeen Area. The Aberdeen Area of APG is located approximately 30 miles northeast of Baltimore at the northern end of the Chesapeake Bay. The Standardized Test Site encompasses 17 acres of upland and lowland flats, woods and wetlands.

2.2.2 Soil Type

According to the soils survey conducted for the entire area of APG in 1998, the test site consists primarily of Elkton Series type soil (ref 2). The Elkton Series consist of very deep, slowly permeable, poorly drained soils. These soils formed in silty aeolin sediments and the underlying loamy alluvial and marine sediments. They are on upland and lowland flats and in depressions of the Mid-Atlantic Coastal Plain. Slopes range from 0 to 2 percent.

ERDC conducted a site-specific analysis in May of 2002 (ref 3). The results basically matched the soil survey mentioned above. Seventy percent of the samples taken were classified as silty loam. The majority (77 percent) of the soil samples had a measured water content between 15- and 30-percent with the water content decreasing slightly with depth.

For more details concerning the soil properties at the APG test site, go to www.uxotestsites.org on the web to view the entire soils description report.

2.2.3 Test Areas

A description of the test site areas at APG is included in Table 2.

TABLE 2. TEST SITE AREAS

Area	Description
Calibration Grid	Contains 14 standard ordnance items buried in six positions at various angles and depths to allow demonstrator to calibrate their equipment.
Blind Test Grid	Contains 400 grid cells in a 0.2-hectare (0.5 acre) site. The center of each grid cell contains ordnance, clutter or nothing.
Open Field	A 4-hectare (10-acre) site containing open areas, dips, ruts, and obstructions that challenge platform systems or hand-held detectors. The challenges include a gravel road, wet areas, and trees. The vegetation height varies from 15 to 25 cm.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (18 and 19 April 2006)

3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total number of hours operated at each site are summarized in Table 3.

TABLE 3. AREAS TESTED AND NUMBER OF HOURS

Area	Number of Hours
Calibration Lanes	1.66
Open Field	14.50

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

An APG weather station located approximately one mile west of the test site was used to record average temperature and precipitation on a half hour basis for each day of operation. The temperatures listed in Table 4 represent the average temperature during field operations from 0700 to 1700 hours while precipitation data represents a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 4. TEMPERATURE/PRECIPITATION DATA SUMMARY

Date, 2006	Average Temperature, °F	Total Daily Precipitation, in.
April 18	61.4	0.00
April 19	68.5	0.00

3.3.2 Field Conditions

The field was dry except for a wet area portion of the open field which had some muddy spots.

3.3.3 Soil Moisture

Three soil probes were placed at various locations within the site to capture soil moisture data: blind grid, calibration, mogul, and wooded areas. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil depths (1 to 6 in., 6 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 48 in.) from each probe. Soil moisture logs are included in Appendix C.

3.4 FIELD ACTIVITIES

3.4.1 Setup/Mobilization

These activities included initial mobilization and daily equipment preparation and breakdown. A two-person crew took 6 hours to perform the initial setup and mobilization. There was 2 hours of daily equipment preparation and end of the day equipment breakdown lasted 1 hour and 25 minutes.

3.4.2 Calibration

Geocenters SAIC spent a total of 1 hour and 40 minutes in the calibration lanes, of which 35 minutes was spent collecting data.

3.4.3 Downtime Occasions

Occasions of downtime are grouped into five categories: equipment/data checks or equipment maintenance, equipment failure and repair, weather, Demonstration Site issues, or breaks/lunch. All downtime is included for the purposes of calculating labor costs (section 5) except for downtime due to Demonstration Site issues. Demonstration Site issues, while noted in the Daily Log, are considered non-chargeable downtime for the purposes of calculating labor costs and are not discussed. Breaks and lunches are discussed in this section and billed to the total Site Survey area.

3.4.3.1 Equipment/data checks, maintenance. Equipment data checks and maintenance activities accounted for 1 hour and 55 minutes of site usage time. These activities included changing out batteries and routine data checks to ensure the data was being properly recorded/collected. Geocenters SAIC spent an additional 40 minutes for breaks and lunches.

3.4.3.2 Equipment failure or repair. No time was needed to resolve equipment failures that occurred while surveying the open field.

3.4.3.3 Weather. No weather delays occurred during the survey.

3.4.4 Data Collection

Geocenters SAIC spent a total time of 14 hours and 30 minutes in the open field area, 8 hours and 30 minutes of which was spent collecting data.

3.4.5 Demobilization

The Geocenters SAIC survey crew went on to conduct a full demonstration of the site. Therefore, demobilization did not occur until 21 April 2006. On that day, it took the crew 2 hours and 35 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

Geocenters SAIC submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data was also provided within the required 30-day timeframe.

3.6 DEMONSTRATOR'S FIELD PERSONNEL

Rob Seigel
2 field support personnel

3.7 DEMONSTRATOR'S FIELD SURVEYING METHOD

Geocenters SAIC surveyed the open field in a linear direction. The team used approximately 2 meters for line spacing and surveyed much of the sight in a north to south manner to obtain the longest lines possible, this minimized numerous turnarounds.

3.8 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are located in Appendix D. Activities pertinent to this specific demonstration are indicated in highlighted text.

SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES

Figure 2, 4, and 6 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive for the EM sensor(s), MAG sensor(s) and combined EM/MAG picks respectively. Figure 3, 5, and 7 shows both probabilities plotted against their respective background alarm rate. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Due to limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the ROC curves presented in figures 4 and 5 of this section are based on the subset of the ground truth that is solely made up of ferrous anomalies.

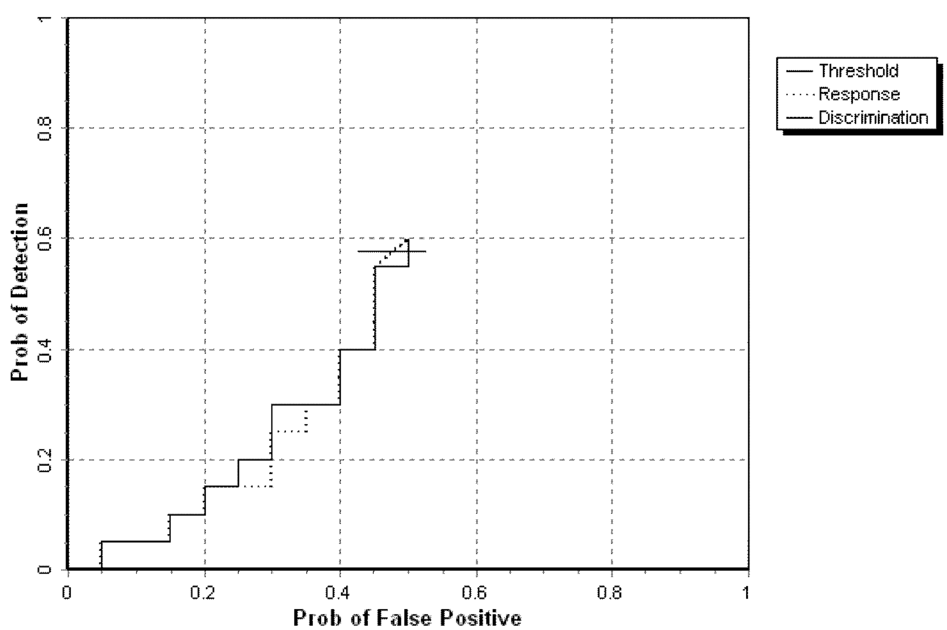

Figure 2. EM SENSOR open field probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

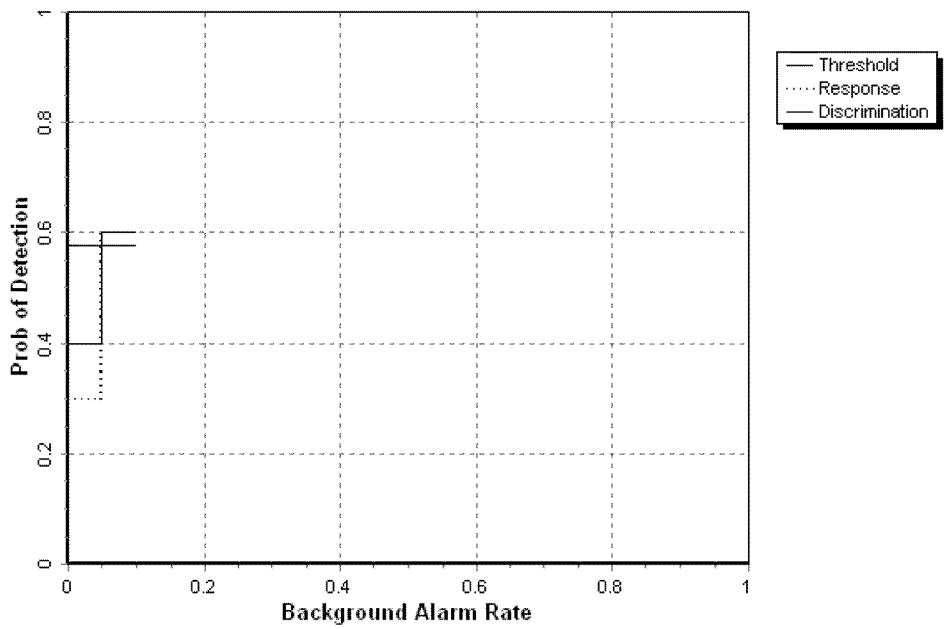

Figure 3. EM Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate over all ordnance categories combined.

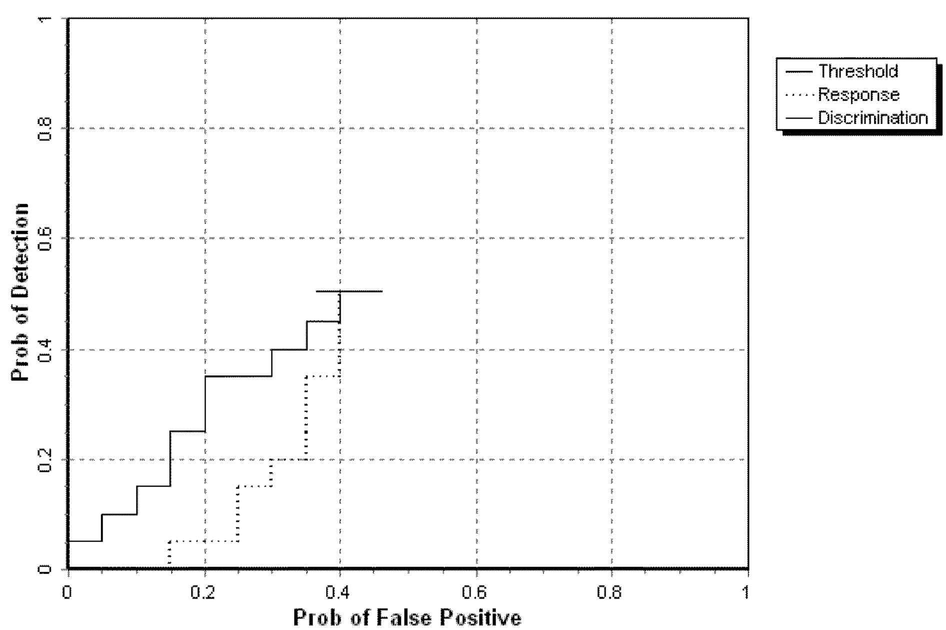

Figure 4. MAG Sensor open field probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

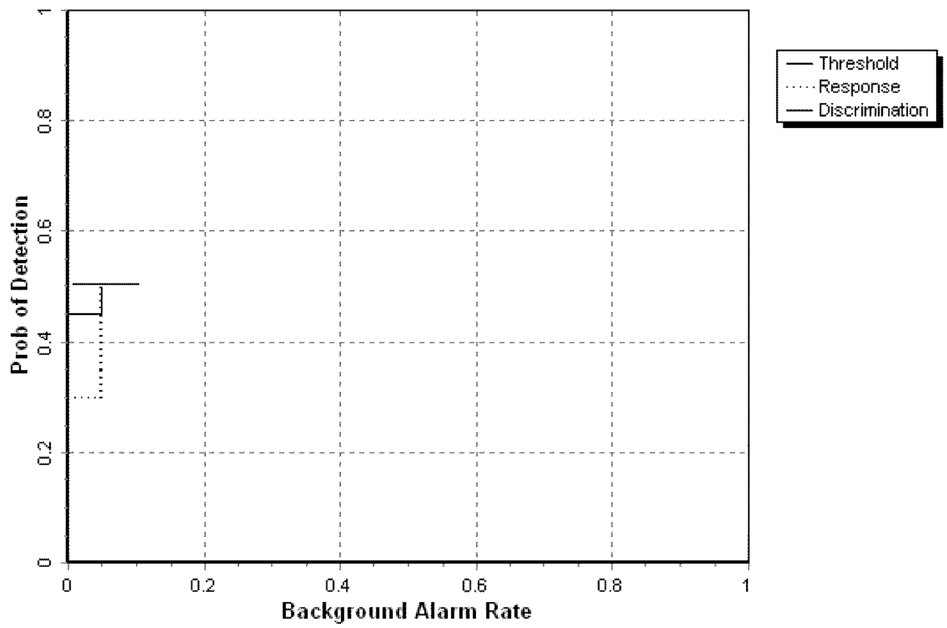

Figure 5. MAG Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate over all ordnance categories combined.

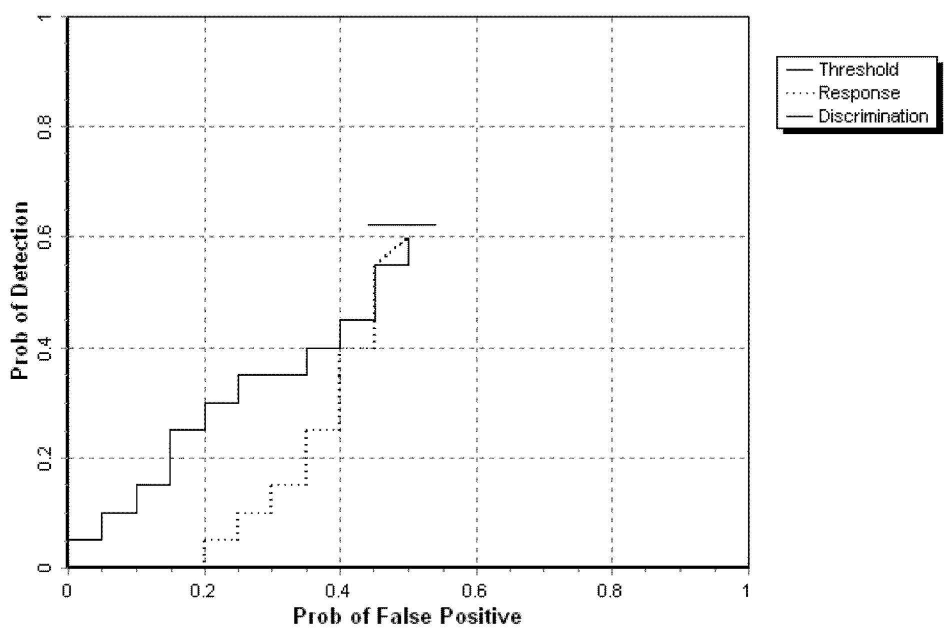

Figure 6. Combined Sensor open field probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

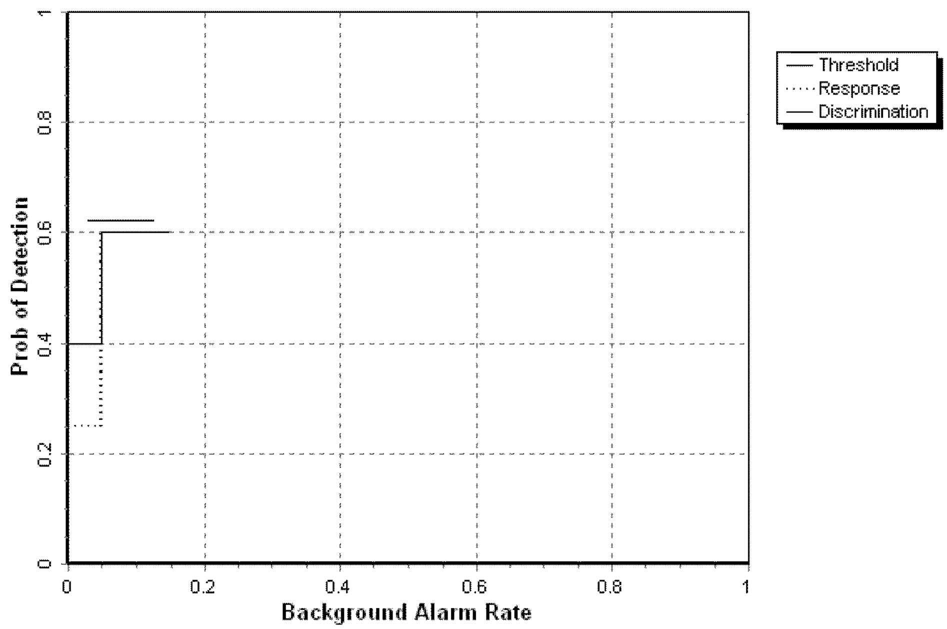

Figure 7. Combined Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate over all ordnance categories combined.

4.2 ROC CURVES USING ORDNANCE LARGER THAN 20 MM

Figure 8, 10, and 12 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive when only targets larger than 20 mm are scored for the EM sensor(s), MAG sensor(s) and Combined EM/MAG picks respectively. Figure 9, 11, and 13 shows both probabilities plotted against their respective background alarm rate. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Due to limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the ROC curves presented in figures 10 and 11 of this section are based on the subset of the ground truth that is solely made up of ferrous anomalies.

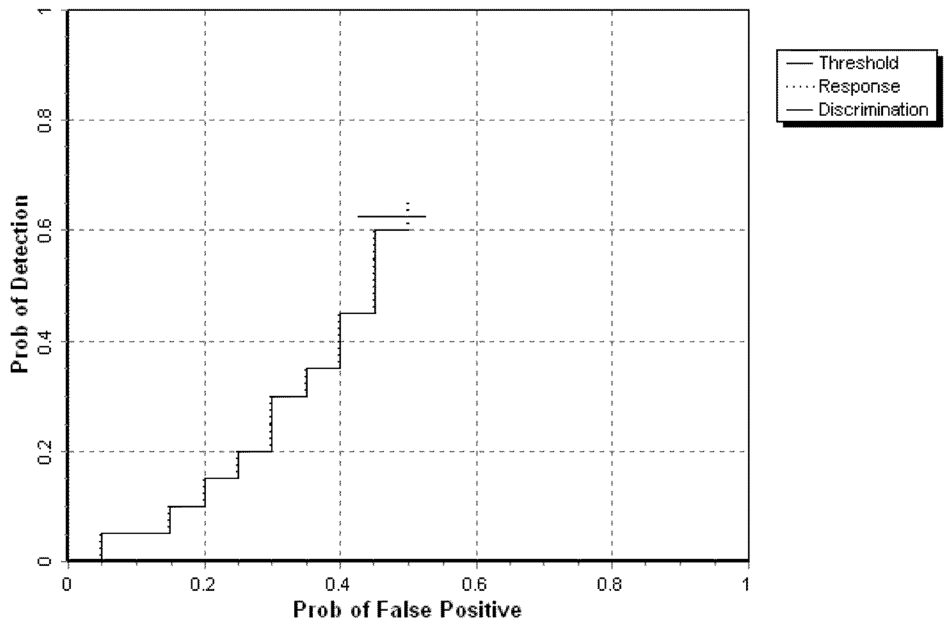

Figure 8. EM Sensor open field probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

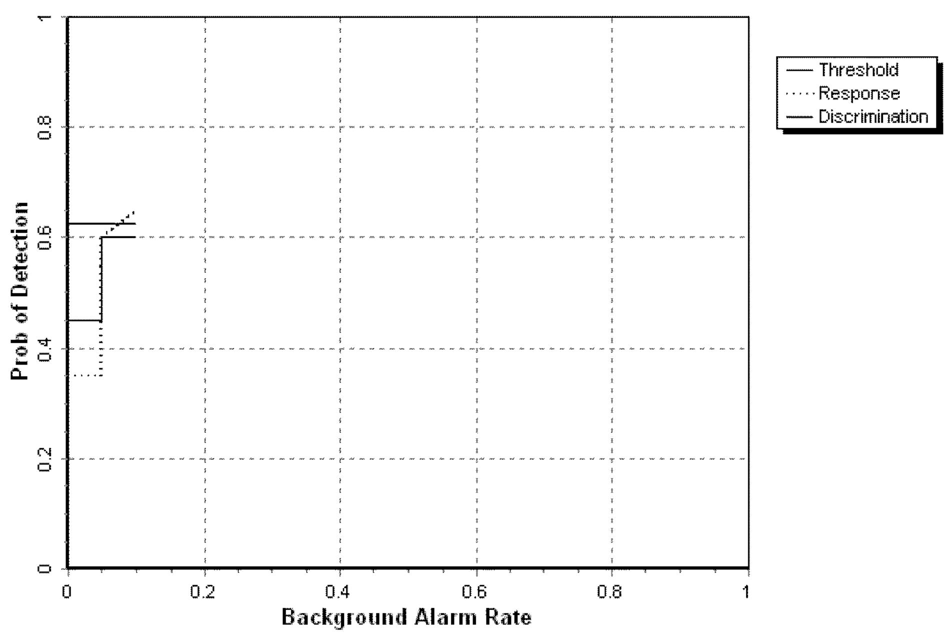

Figure 9. EM Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate for all ordnance larger than 20 mm.

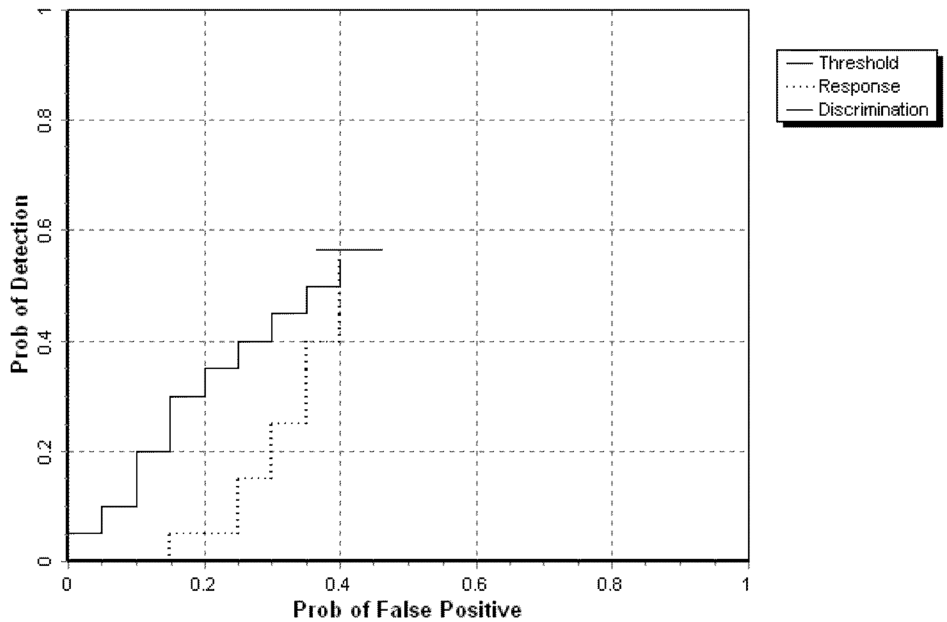

Figure 10. MAG Sensor open field probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

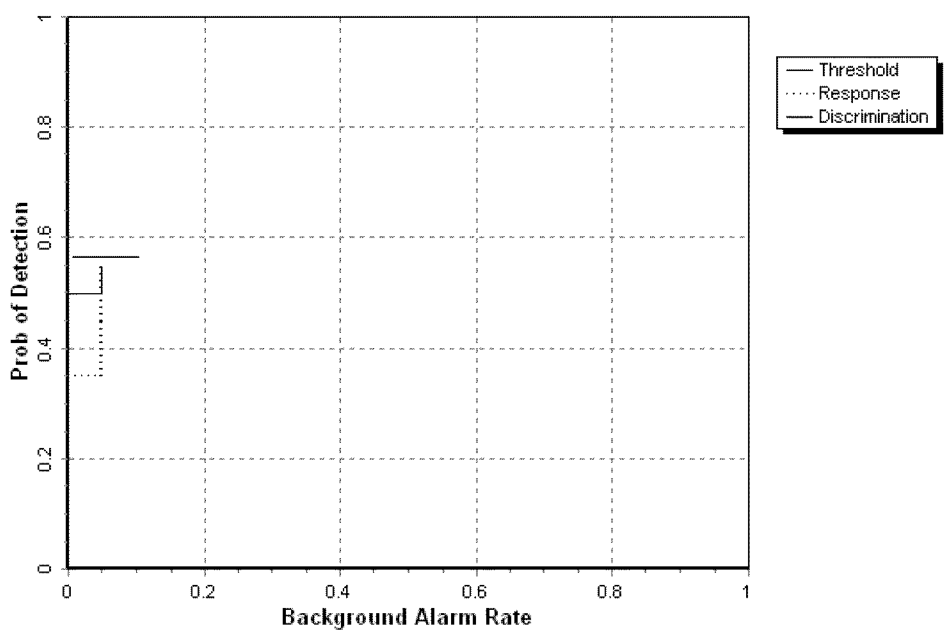

Figure 11. MAG Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate for all ordnance larger than 20 mm.

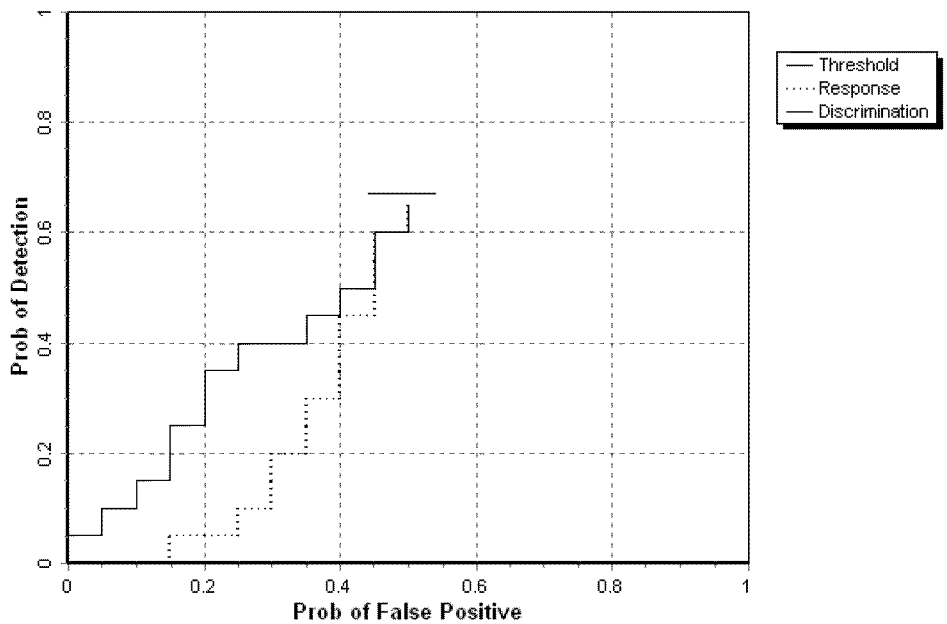

Figure 12. Combined Sensor open field probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

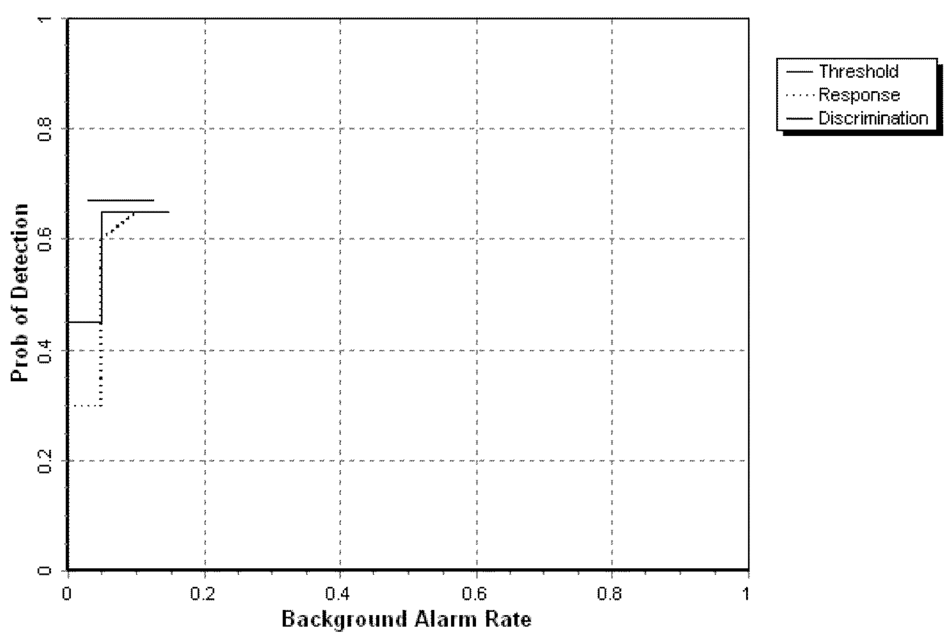

Figure 13. Combined Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate for all ordnance larger than 20 mm.

4.3 PERFORMANCE SUMMARIES

Results for the open field test broken out by sensor type, size, depth and nonstandard ordnance are presented in Tables 5a, b, and c (for cost results, see section 5). Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range (see app A for size definitions). The results are relative to the number of ordnance items emplaced. Depth is measured from the geometric center of anomalies.

The RESPONSE STAGE results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the DISCRIMINATION STAGE are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence limit on probability of detection and P_{fp} was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in Table 5 have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Due to limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the summary presented in table 5b is split exhibiting results based on the subset of the ground truth that is solely the ferrous anomalies and the full ground truth for comparison purposes.

All other tables presented in this section are based on scoring against the ferrous only ground truth. The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.

TABLE 5a. SUMMARY OF OPEN FIELD RESULTS FOR THE VSEMS DUAL/TOWED (EM SENSOR)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.60	0.65	0.55	0.55	0.60	0.80	0.65	0.60	0.50
P_d Low 90% Conf	0.59	0.62	0.47	0.49	0.56	0.72	0.61	0.56	0.41
P_d Upper 90% Conf	0.65	0.70	0.59	0.60	0.66	0.86	0.69	0.68	0.59
P_{fp}	0.50	-	-	-	-	-	0.40	0.55	0.80
P_{fp} Low 90% Conf	0.47	-	-	-	-	-	0.39	0.53	0.63
P_{fp} Upper 90% Conf	0.52	-	-	-	-	-	0.45	0.59	0.93
BAR	0.10	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.60	0.65	0.45	0.45	0.60	0.75	0.60	0.55	0.50
P_d Low 90% Conf	0.54	0.60	0.41	0.41	0.54	0.69	0.56	0.51	0.39
P_d Upper 90% Conf	0.61	0.68	0.52	0.52	0.65	0.83	0.65	0.63	0.57
P_{fp}	0.50	-	-	-	-	-	0.40	0.55	0.80
P_{fp} Low 90% Conf	0.46	-	-	-	-	-	0.36	0.52	0.63
P_{fp} Upper 90% Conf	0.50	-	-	-	-	-	0.42	0.59	0.93
BAR	0.05	-	-	-	-	-	-	-	-

Response Stage Noise Level: 3.00
Recommended Discrimination Stage Threshold: 249.50

TABLE 5b. SUMMARY OF OPEN FIELD RESULTS FOR THE VSEMS DUAL/TOWED (MAG SENSOR)

Ferrous Only Ground Truth									
				By Size			By Depth, m		
Metric	**Overall**	**Standard**	**Nonstandard**	**Small**	**Medium**	**Large**	**< 0.3**	**0.3 to <1**	**>= 1**
RESPONSE STAGE									
P_d	0.50	0.55	0.45	0.30	0.50	0.80	0.45	0.45	0.70
P_d Low 90% Conf	0.47	0.49	0.39	0.22	0.46	0.75	0.42	0.40	0.59
P_d Upper 90% Conf	0.54	0.58	0.51	0.34	0.56	0.88	0.52	0.53	0.76
P_{fp}	0.40	-	-	-	-	-	0.35	0.50	0.75
P_{fp} Low 90% Conf	0.39	-	-	-	-	-	0.30	0.46	0.56
P_{fp} Upper 90% Conf	0.44	-	-	-	-	-	0.36	0.52	0.89
BAR	0.05	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A
P_d Low 90% Conf	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A
P_d Upper 90% Conf	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A
P_{fp}	N\A	-	-	-	-	-	N\A	N\A	N\A
P_{fp} Low 90% Conf	N\A	-	-	-	-	-	N\A	N\A	N\A
P_{fp} Upper 90% Conf	N\A	-	-	-	-	-	N\A	N\A	N\A
BAR	N\A	-	-	-	-	-	-	-	-

Full Ground Truth									
				By Size			By Depth, m		
Metric	**Overall**	**Standard**	**Nonstandard**	**Small**	**Medium**	**Large**	**< 0.3**	**0.3 to <1**	**>= 1**
RESPONSE STAGE									
P_d	0.45	0.50	0.40	0.20	0.50	0.80	0.40	0.40	0.65
P_d Low 90% Conf	0.42	0.44	0.34	0.16	0.46	0.75	0.36	0.36	0.58
P_d Upper 90% Conf	0.48	0.52	0.46	0.25	0.56	0.88	0.45	0.49	0.75
P_{fp}	0.40	-	-	-	-	-	0.35	0.50	0.75
P_{fp} Low 90% Conf	0.39	-	-	-	-	-	0.30	0.46	0.56
P_{fp} Upper 90% Conf	0.44	-	-	-	-	-	0.36	0.52	0.89
BAR	0.05	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A
P_d Low 90% Conf	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A
P_d Upper 90% Conf	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A
P_{fp}	N\A	-	-	-	-	-	N\A	N\A	N\A
P_{fp} Low 90% Conf	N\A	-	-	-	-	-	N\A	N\A	N\A
P_{fp} Upper 90% Conf	N\A	-	-	-	-	-	N\A	N\A	N\A
BAR	N\A	-	-	-	-	-	-	-	-

Response Stage Noise Level: 4.00
Recommended Discrimination Stage Threshold: 28.50.

TABLE 5c. SUMMARY OF OPEN FIELD RESULTS FOR THE VSEMS DUAL/TOWED (COMBINED EM/MAG RESULTS)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.65	0.70	0.60	0.55	0.65	0.90	0.65	0.65	0.70
P_d Low 90% Conf	0.63	0.66	0.53	0.51	0.60	0.83	0.62	0.57	0.63
P_d Upper 90% Conf	0.69	0.74	0.64	0.62	0.70	0.94	0.71	0.69	0.79
P_{fp}	0.50	-	-	-	-	-	0.45	0.55	0.80
P_{fp} Low 90% Conf	0.49	-	-	-	-	-	0.41	0.54	0.63
P_{fp} Upper 90% Conf	0.53	-	-	-	-	-	0.47	0.60	0.93
BAR	0.15	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.60	0.65	0.50	0.50	0.65	0.85	0.60	0.60	0.70
P_d Low 90% Conf	0.59	0.63	0.46	0.43	0.59	0.80	0.58	0.51	0.61
P_d Upper 90% Conf	0.65	0.71	0.58	0.54	0.69	0.91	0.67	0.64	0.78
P_{fp}	0.50	-	-	-	-	-	0.40	0.55	0.80
P_{fp} Low 90% Conf	0.47	-	-	-	-	-	0.38	0.53	0.63
P_{fp} Upper 90% Conf	0.51	-	-	-	-	-	0.44	0.59	0.93
BAR	0.10	-	-	-	-	-	-	-	-

Response Stage Noise Level: 4.00
Recommended Discrimination Stage Threshold: 277.50

Note: The recommended discrimination stage threshold values are provided by the demonstrator.

4.4 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION (All results based on combined EM/MAG data set)

Efficiency and rejection rates are calculated to quantify the discrimination ability at specific points of interest on the ROC curve: (1) at the point where no decrease in P_d is suffered (i.e., the efficiency is by definition equal to one) and (2) at the operator selected threshold. These values are reported in Table 6.

TABLE 6. EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	0.94	0.04	0.38
With No Loss of P_d	1.00	0.00	0.01

At the demonstrator's recommended setting, the ordnance items that were detected and correctly discriminated were further scored on whether their correct type could be identified (table 7). Correct type examples include "20-mm projectile, 105-mm HEAT Projectile, and 2.75-inch Rocket". A list of the standard type declaration required for each ordnance item was provided to demonstrators prior to testing. For example, the standard type for the three example items are 20mmP, 105H, and 2.75in, respectively.

TABLE 7. CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS UXO

Size	Percentage Correct
Small	0.00
Medium	0.00
Large	0.00
Overall	0.00

Note: The demonstrator did not attempt to provide type classification.

4.5 LOCATION ACCURACY

The mean location error and standard deviations appear in Table 8. These calculations are based on average missed depth for ordnance correctly identified in the discrimination stage. Depths are measured from the closest point of the ordnance to the surface. For the blind grid, only depth errors are calculated, since (X, Y) positions are known to be the centers of each grid square.

TABLE 8. MEAN LOCATION ERROR AND STANDARD DEVIATION (M)

	Mean	Standard Deviation
Northing	-0.01	0.18
Easting	-0.03	0.16
Depth	0.14	0.29

SECTION 5. ON-SITE LABOR COSTS

A standardized estimate for labor costs associated with this effort was calculated as follows: the first person at the test site was designated "supervisor", the second person was designated "data analyst", and the third and following personnel were considered "field support". Standardized hourly labor rates were charged by title: supervisor at $95.00/hour, data analyst at $57.00/hour, and field support at $28.50/hour.

Government representatives monitored on-site activity. All on-site activities were grouped into one of ten categories: initial setup/mobilization, daily setup/stop, calibration, collecting data, downtime due to break/lunch, downtime due to equipment failure, downtime due to equipment/data checks or maintenance, downtime due to weather, downtime due to demonstration site issue, or demobilization. See Appendix D for the daily activity log. See section 3.4 for a summary of field activities.

The standardized cost estimate associated with the labor needed to perform the field activities is presented in Table 9. Note that calibration time includes time spent in the Calibration Lanes as well as field calibrations. "Site survey time" includes daily setup/stop time, collecting data, breaks/lunch, downtime due to equipment/data checks or maintenance, downtime due to failure, and downtime due to weather.

TABLE 9. ON-SITE LABOR COSTS

	No. People	Hourly Wage	Hours	Cost
		Initial Setup		
Supervisor	1	$95.00	6.0	$570.00
Data Analyst	0	57.00	6.0	0.00
Field Support	1	28.50	6.0	171.00
SubTotal				**$741.00**
		Calibration		
Supervisor	1	$95.00	1.66	$157.70
Data Analyst	0	57.00	1.66	0.00
Field Support	2	28.50	1.66	94.62
SubTotal				**$252.32**
		Site Survey		
Supervisor	1	$95.00	14.50	$1,377.50
Data Analyst	0	57.00	14.50	0.00
Field Support	2	28.50	14.50	826.50
SubTotal				**$2,204.00**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	1	$95.00	2.58	$245.10
Data Analyst	0	57.00	2.58	0.00
Field Support	2	28.50	2.58	147.06
Subtotal				**$392.16**
Total				**$3,589.48**

Notes: Calibration time includes time spent in the Calibration Lanes as well as calibration before each data run.
Site Survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to system maintenance, failure, and weather.

SECTION 6. COMPARISON OF RESULTS TO BLIND GRID DEMONSTRATION (BASED ON COMBINED EM/MAG DATA SETS)

6.1 SUMMARY OF RESULTS FROM BLIND GRID DEMONSTRATION

Table 10 shows the results from the blind grid survey conducted prior to surveying the open field during the same site visit in April of 2006. Due to the system utilizing magnetometer type sensors, all results presented in the following section have been based on performance scoring against the ferrous only ground truth anomalies. For more details on the blind grid survey results reference section 2.1.6.

TABLE 10. SUMMARY OF BLIND GRID RESULTS FOR THE VSEMS DUAL/TOWED

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.65	0.70	0.55	0.60	0.65	0.90	0.75	0.75	0.45
P_d Low 90% Conf	0.58	0.61	0.45	0.50	0.51	0.66	0.62	0.62	0.26
P_d Upper 90% Conf	0.72	0.79	0.69	0.71	0.75	0.99	0.84	0.84	0.62
P_{fp}	0.70	-	-	-	-	-	0.75	0.75	0.50
P_{fp} Low 90% Conf	0.66	-	-	-	-	-	0.63	0.63	0.20
P_{fp} Upper 90% Conf	0.78	-	-	-	-	-	0.83	0.83	0.80
P_{ba}	0.05	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.65	0.70	0.55	0.60	0.60	0.90	0.70	0.70	0.45
P_d Low 90% Conf	0.57	0.61	0.42	0.50	0.48	0.66	0.59	0.59	0.26
P_d Upper 90% Conf	0.71	0.79	0.66	0.71	0.72	0.99	0.81	0.81	0.62
P_{fp}	0.60	-	-	-	-	-	0.60	0.60	0.50
P_{fp} Low 90% Conf	0.53	-	-	-	-	-	0.51	0.51	0.20
P_{fp} Upper 90% Conf	0.67	-	-	-	-	-	0.72	0.72	0.80
P_{ba}	0.05	-	-	-	-	-	-	-	-

6.2 COMPARISON OF ROC CURVES USING ALL ORDNANCE CATEGORIES

Figure 6 shows P_d^{res} versus the respective P_{fp} over all ordnance categories. Figure 7 shows P_d^{disc} versus their respective P_{fp} over all ordnance categories. Figure 7 uses horizontal lines to illustrate the performance of the demonstrator at the recommended discrimination threshold levels, defining the subset of targets the demonstrator would recommend digging based on discrimination. The ROC curves in this section are a sole reflection of the ferrous only survey.

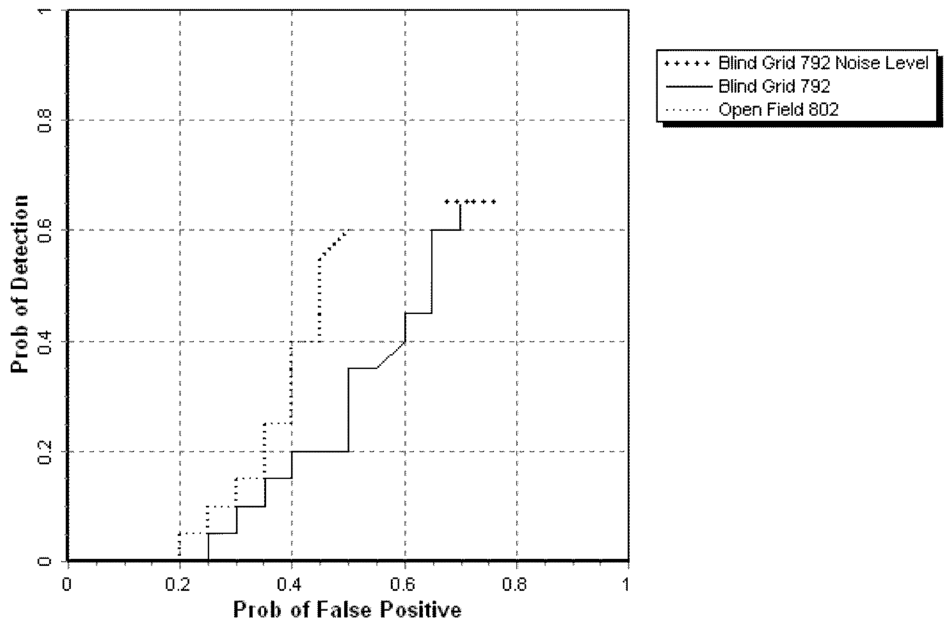

Figure 14. VSEMS dual/towed P_d^{res} stages versus the respective P_{fp} over all ordnance categories combined.

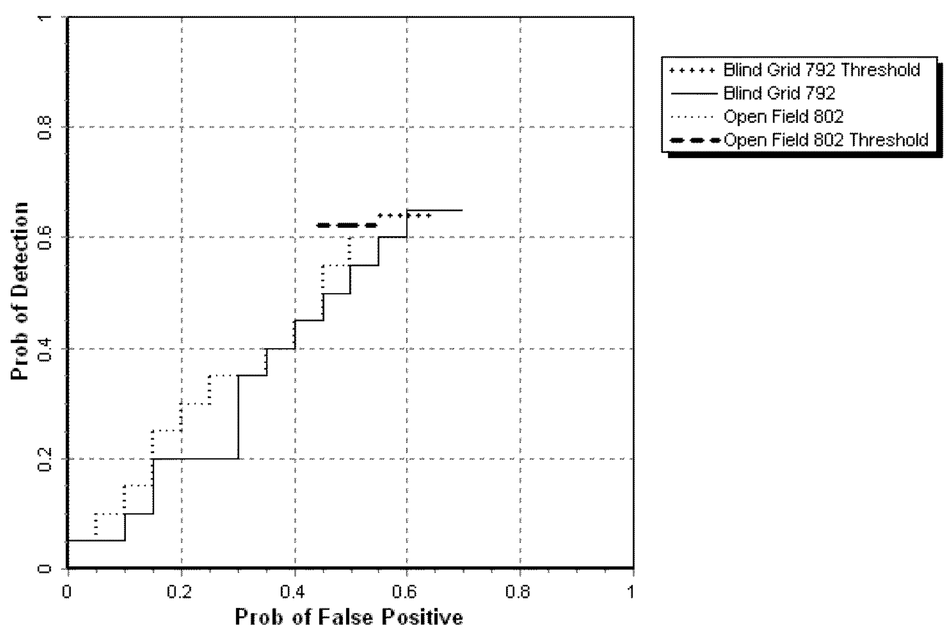

Figure 15. VSEMS dual/towed P_d^{disc} versus the respective P_{fp} over all ordnance categories combined.

6.3 COMPARISON OF ROC CURVES USING ORDNANCE LARGER THAN 20 MM

Figure 8 shows the P_d^{res} versus the respective probability of P_{fp} over ordnance larger than 20 mm. Figure 9 shows P_d^{disc} versus the respective P_{fp} over ordnance larger than 20 mm. Figure 9 uses horizontal lines to illustrate the performance of the demonstrator at the recommended discrimination threshold levels, defining the subset of targets the demonstrator would recommend digging based on discrimination.

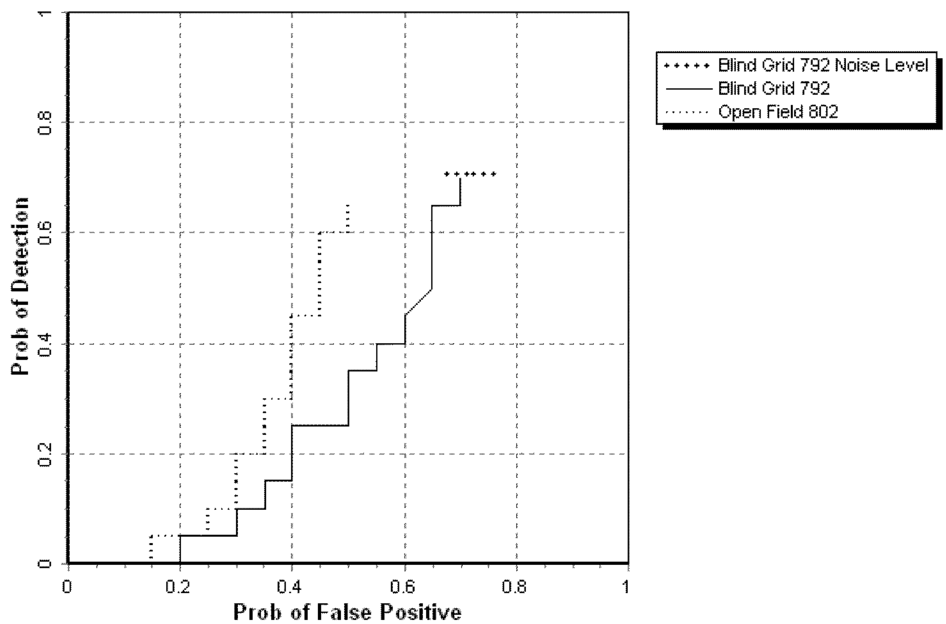

Figure 16. VSEMS dual/towed P_d^{res} versus the respective P_{fp} for ordnance larger than 20 mm.

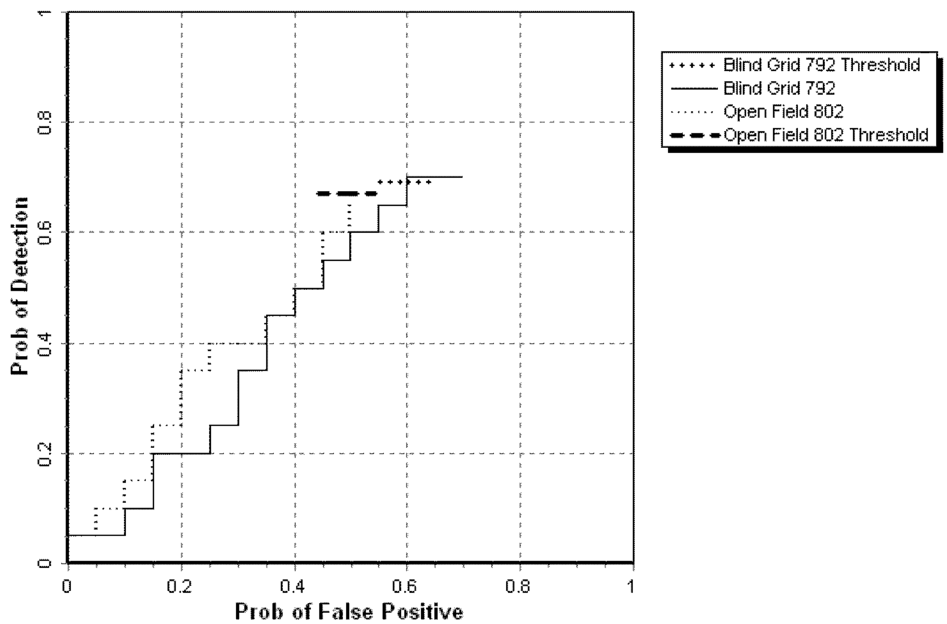

Figure 17. VSEMS dual/towed P_d^{disc} versus the respective P_{fp} for ordnance larger than 20 mm.

6.4 STATISTICAL COMPARISONS

Statistical Chi-square significance tests were used to compare results between the blind grid and open field scenarios. The intent of the comparison is to determine if the feature introduced in each scenario has a degrading effect on the performance of the sensor system. However, any modifications in the UXO sensor system during the test, like changes in the processing or changes in the selection of the operating threshold, will also contribute to performance differences.

The Chi-square test for comparison between ratios was used at a significance level of 0.05 to compare blind grid to open field with regard to P_d^{res}, P_d^{disc}, P_{fp}^{res} and P_{fp}^{disc}, Efficiency and Rejection Rate. These results are presented in Table 11. A detailed explanation and example of the Chi-square application is located in Appendix A.

TABLE 11. CHI-SQUARE RESULTS - BLIND GRID VERSUS OPEN FIELD

Metric	Small	Medium	Large	Overall
P_d^{res}	Not Significant	Not Significant	Not Significant	Not Significant
P_d^{disc}	Not Significant	Not Significant	Not Significant	Not Significant
P_{fp}^{res}				Not Significant
P_{fp}^{disc}	-	-	-	Significant
Efficiency	-			Significant
Rejection rate	-	-	-	Significant

SECTION 7. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced ordnance item.

Detection: An anomaly location that is within R_{halo} of an emplaced ordnance item.

Munitions and Explosives Of Concern (MEC): Specific categories of military munitions that may pose unique explosive safety risks, including UXO as defined in 10 USC 101(e)(5), DMM as defined in 10 USC 2710(e)(2) and/or munitions constituents (e.g. TNT, RDX) as defined in 10 USC 2710(e)(3) that are present in high enough concentrations to pose an explosive hazard.

Emplaced Ordnance: An ordnance item buried by the government at a specified location in the test site.

Emplaced Clutter: A clutter item (i.e., non-ordnance item) buried by the government at a specified location in the test site.

R_{halo}: A pre-determined radius about the periphery of an emplaced item (clutter or ordnance) within which a location identified by the demonstrator as being of interest is considered to be a response from that item. If multiple declarations lie within R_{halo} of any item (clutter or ordnance), the declaration with the highest signal output within the R_{halo} will be utilized. For the purpose of this program, a circular halo 0.5 meters in radius will be placed around the center of the object for all clutter and ordnance items less than 0.6 meters in length. When ordnance items are longer than 0.6 meters, the halo becomes an ellipse where the minor axis remains 1 meter and the major axis is equal to the length of the ordnance plus 1 meter.

Small Ordnance: Caliber of ordnance less than or equal to 40 mm (includes 20-mm projectile, 40-mm projectile, submunitions BLU-26, BLU-63, and M42).

Medium Ordnance: Caliber of ordnance greater than 40 mm and less than or equal to 81 mm (includes 57-mm projectile, 60-mm mortar, 2.75 in. Rocket, MK118 Rockeye, 81-mm mortar).

Large Ordnance: Caliber of ordnance greater than 81 mm (includes 105-mm HEAT, 105-mm projectile, 155-mm projectile, 500-pound bomb).

Shallow: Items buried less than 0.3 meter below ground surface.

Medium: Items buried greater than or equal to 0.3 meter and less than 1 meter below ground surface.

Deep: Items buried greater than or equal to 1 meter below ground surface.

Response Stage Noise Level: The level that represents the point below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the Blind Grid test area.

Discrimination Stage Threshold: The demonstrator selected threshold level that they believe provides optimum performance of the system by retaining all detectable ordnance and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for n independent trials with the probability p of success and the probability 1-p of failure being the same for each trial. The number of successes x observed in the n trials is an estimate of p and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}) and those that do not correspond to any known item, termed background alarms.

The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the RESPONSE STAGE, the demonstrator provides the scoring committee with the location and signal strength of all anomalies that the demonstrator has deemed sufficient to warrant further investigation and/or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.

The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the RESPONSE STAGE anomaly list, the DISCRIMINATION STAGE list contains the output of the algorithms applied in the discrimination-stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide "optimum" system performance, (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection (P_d^{res}): P_d^{res} = (No. of response-stage detections)/(No. of emplaced ordnance in the test site).

Response Stage False Positive (fp^{res}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Response Stage Probability of False Positive (P_{fp}^{res}): P_{fp}^{res} = (No. of response-stage false positives)/(No. of emplaced clutter items).

Response Stage Background Alarm (ba^{res}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Response Stage Probability of Background Alarm (P_{ba}^{res}): Blind Grid only: P_{ba}^{res} = (No. of response-stage background alarms)/(No. of empty grid locations).

Response Stage Background Alarm Rate (BAR^{res}): Open Field only: BAR^{res} = (No. of response-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{res}, P_{fp}^{res}, P_{ba}^{res}, and BAR^{res} are functions of t^{res}, the threshold applied to the response-stage signal strength. These quantities can therefore be written as $P_d^{res}(t^{res})$, $P_{fp}^{res}(t^{res})$, $P_{ba}^{res}(t^{res})$, and $BAR^{res}(t^{res})$.

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to response-stage data that discriminates ordnance from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to ordnance, as well as those that the demonstrator has high confidence correspond to non-ordnance or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{disc}): P_d^{disc} = (No. of discrimination-stage detections)/(No. of emplaced ordnance in the test site).

Discrimination Stage False Positive (fp^{disc}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Discrimination Stage Probability of False Positive (P_{fp}^{disc}): P_{fp}^{disc} = (No. of discrimination stage false positives)/(No. of emplaced clutter items).

Discrimination Stage Background Alarm (ba^{disc}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Discrimination Stage Probability of Background Alarm (P_{ba}^{disc}): P_{ba}^{disc} = (No. of discrimination-stage background alarms)/(No. of empty grid locations).

Discrimination Stage Background Alarm Rate (BAR^{disc}): BAR^{disc} = (No. of discrimination-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{disc}, P_{fp}^{disc}, P_{ba}^{disc}, and BAR^{disc} are functions of t^{disc}, the threshold applied to the discrimination-stage signal strength. These quantities can therefore be written as $P_d^{disc}(t^{disc})$, $P_{fp}^{disc}(t^{disc})$, $P_{ba}^{disc}(t^{disc})$, and $BAR^{disc}(t^{disc})$.

RECEIVER-OPERATING CHARACERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between P_d versus P_{fp} and P_d versus BAR or P_{ba} as the threshold applied to the signal strength is varied from its minimum (t_{min}) to its maximum (t_{max}) value.[1] Figure A-1 shows how P_d versus P_{fp} and P_d versus BAR are combined into ROC curves. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

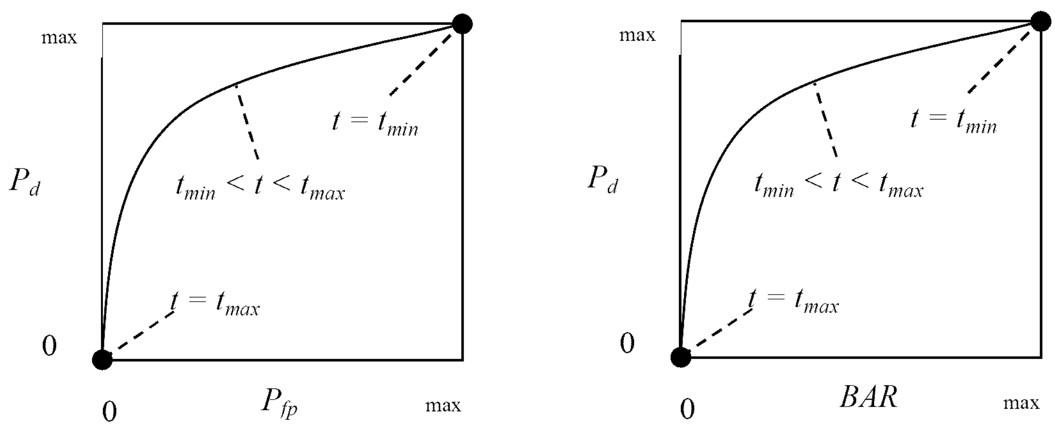

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

[1]Strictly speaking, ROC curves plot the P_d versus P_{ba} over a pre-determined and fixed number of detection opportunities (some of the opportunities are located over ordnance and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the Blind Grid test sites are true ROC curves.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from non-ordnance items. The efficiency measures the amount of detected ordnance retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$; Measures (at a threshold of interest), the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage tmin) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage, t^{disc}.

False Positive Rejection Rate (R_{fp}): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})]$; Measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage tmin). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate (R_{ba}):

Blind Grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$.
Open Field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})])$.

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON EXPLANATION:

The Chi-square test for differences in probabilities (or 2 x 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations (ref 3).

A 2 x 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to determine if there is reason to believe that the proportion of ordnance correctly detected/discriminated by demonstrator X's system is significantly degraded by the more challenging terrain feature introduced. The test statistic of the 2 x 2 contingency table is the

Chi-square distribution with one degree of freedom. Since an association between the more challenging terrain feature and relatively degraded performance is sought, a one-sided test is performed. A significance level of 0.05 is chosen which sets a critical decision limit of 3.84 from the Chi-square distribution with one degree of freedom. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, the two proportions tested will be considered significantly different. If the test statistic calculated from the data is less than this value, the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The Chi-square test cannot be used in these instances. Instead, Fischer's test is used and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, the proportions are considered to be significantly different.

Standardized UXO Technology Demonstration Site examples, where blind grid results are compared to those from the open field and open field results are compared to those from one of the scenarios, follow. It should be noted that a significant result does not prove a cause and effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying each of the three progressively more difficult areas using the same system (results indicate the number of ordnance detected divided by the number of ordnance emplaced):

	Blind Grid	Open Field	Moguls
P_d^{res}	100/100 = 1.0	8/10 = .80	20/33 = .61
P_d^{disc}	80/100 = 0.80	6/10 = .60	8/33 = .24

P_d^{res}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the response stage, all 100 ordnance out of 100 emplaced ordnance items were detected in the blind grid while 8 ordnance out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system.

P_d^{disc}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the discrimination stage, 80 out of 100 emplaced ordnance items were correctly discriminated as ordnance in blind grid testing while 6 ordnance out of 10 emplaced were correctly discriminated as such in open field-testing. Those four values are used to calculate a test statistic of 1.12. Since the test statistic is less than the critical value of 3.84, the two discrimination stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{res}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the response stage, 8 out of 10 and 20 out of 33 are used to calculate a test statistic of 0.56. Since the test statistic is less than the critical value of 3.84, the two response stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{disc}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the discrimination stage, 6 out of 10 and 8 out of 33 are used to calculate a test statistic of 2.98. Since the test statistic is greater than the critical value of 3.84, the smaller discrimination stage detection rate is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the ability of demonstrator X to correctly discriminate seems to have been degraded by the mogul terrain relative to results from the flat open field using the same system.

APPENDIX B. DAILY WEATHER LOGS

Date	Time, EST	Time, EDT	Average Temperature, °F	Maximum Temperature, °F	Minimum Temperature, °F	Average RH, %
4/17/2006	0100	200	58.2	59.6	57.0	34
4/17/2006	0200	300	56.1	57.5	54.7	37
4/17/2006	0300	400	55.0	55.8	53.8	41
4/17/2006	0400	500	52.8	53.9	52.1	46
4/17/2006	0500	600	51.5	52.5	50.6	48
4/17/2006	0600	700	50.3	50.9	49.6	50
4/17/2006	0700	800	50.7	51.3	49.9	51
4/17/2006	0800	900	51.9	52.6	50.9	52
4/17/2006	0900	1000	53.3	54.4	52.0	52
4/17/2006	1000	1100	54.9	56.2	54.0	50
4/17/2006	1100	1200	57.1	58.9	55.9	47
4/17/2006	1200	1300	60.1	61.6	58.3	44
4/17/2006	1300	1400	61.4	62.4	60.6	40
4/17/2006	1400	1500	62.9	64.3	61.5	37
4/17/2006	1500	1600	65.1	66.1	64.1	35
4/17/2006	1600	1700	65.2	66.3	64.4	32
4/17/2006	1700	1800	65.0	65.7	64.6	32
4/17/2006	1800	1900	64.8	65.3	63.8	32
4/17/2006	1900	2000	62.9	64.1	60.9	33
4/17/2006	2000	2100	60.5	61.6	59.1	37
4/17/2006	2100	2200	57.0	59.5	52.9	47
4/17/2006	2200	2300	54.0	56.4	50.5	64
4/17/2006	2300	000	50.8	52.0	48.9	74
4/17/2006	2359	059	49.3	50.6	47.9	72
4/18/2006	0100	200	48.4	50.2	47.4	78
4/18/2006	0200	300	46.7	47.9	45.4	84
4/18/2006	0300	400	45.0	46.1	43.1	86
4/18/2006	0400	500	45.6	48.4	43.4	82
4/18/2006	0500	600	48.1	48.7	47.5	71
4/18/2006	0600	700	47.9	48.7	47.2	69
4/18/2006	0700	800	49.8	51.4	48.3	66
4/18/2006	0800	900	52.9	54.6	51.0	59
4/18/2006	0900	1000	55.2	56.5	53.9	55
4/18/2006	1000	1100	57.3	58.7	56.0	54
4/18/2006	1100	1200	59.4	60.9	57.5	51
4/18/2006	1200	1300	61.7	62.7	60.3	49
4/18/2006	1300	1400	64.1	65.8	62.4	47
4/18/2006	1400	1500	66.6	68.3	64.9	43
4/18/2006	1500	1600	68.5	69.6	67.6	37

Date	Time, EST	Time, EDT	Average Temperature, °F	Maximum Temperature, °F	Minimum Temperature, °F	Average RH, %
4/18/2006	1600	1700	69.7	70.8	68.9	35
4/18/2006	1700	1800	70.4	71.1	69.6	33
4/18/2006	1800	1900	70.8	71.5	69.6	32
4/18/2006	1900	2000	67.9	70.1	65.4	35
4/18/2006	2000	2100	61.5	65.6	60.0	55
4/18/2006	2100	2200	58.9	60.3	57.5	71
4/18/2006	2200	2300	56.9	58.3	55.3	78
4/18/2006	2300	000	56.8	58.0	55.2	66
4/18/2006	2359	059	59.1	60.7	56.0	52
4/19/2006	0100	200	59.9	60.5	59.3	50
4/19/2006	0200	300	59.1	59.9	58.2	53
4/19/2006	0300	400	58.1	58.7	57.1	55
4/19/2006	0400	500	56.7	57.6	55.8	58
4/19/2006	0500	600	55.4	56.3	54.3	61
4/19/2006	0600	700	54.3	54.9	53.8	63
4/19/2006	0700	800	56.2	58.5	54.4	61
4/19/2006	0800	900	60.2	61.8	58.3	53
4/19/2006	0900	1000	63.0	64.9	61.5	48
4/19/2006	1000	1100	65.6	67.3	64.4	42
4/19/2006	1100	1200	67.4	68.7	66.3	41
4/19/2006	1200	1300	69.5	70.5	68.2	39
4/19/2006	1300	1400	71.9	73.6	70.1	36
4/19/2006	1400	1500	73.7	74.9	72.0	31
4/19/2006	1500	1600	75.0	75.8	74.2	28
4/19/2006	1600	1700	75.8	76.6	75.2	27
4/19/2006	1700	1800	76.1	76.7	75.7	24
4/19/2006	1800	1900	75.9	76.4	75.3	22
4/19/2006	1900	2000	74.1	75.6	72.5	21
4/19/2006	2000	2100	71.0	72.9	68.2	23
4/19/2006	2100	2200	67.2	68.9	65.0	27
4/19/2006	2200	2300	66.6	67.9	65.9	26
4/19/2006	2300	000	66.3	66.9	65.6	27
4/19/2006	2359	059	64.4	65.7	63.2	31
4/20/2006	0100	200	62.0	63.7	59.4	36
4/20/2006	0200	300	60.2	61.2	59.0	41
4/20/2006	0300	400	59.0	59.9	58.4	41
4/20/2006	0400	500	58.5	59.3	57.8	42
4/20/2006	0500	600	58.8	59.3	58.1	41
4/20/2006	0600	700	52.8	58.5	48.4	57
4/20/2006	0700	800	57.2	63.3	50.3	53
4/20/2006	0800	900	65.1	67.2	63.3	37
4/20/2006	0900	1000	68.7	70.9	67.0	34
4/20/2006	1000	1100	72.1	73.3	70.6	30
4/20/2006	1100	1200	74.7	76.8	72.5	26

Date	Time, EST	Time, EDT	Average Temperature, °F	Maximum Temperature, °F	Minimum Temperature, °F	Average RH, %
4/20/2006	1200	1300	77.8	80.0	76.0	23
4/20/2006	1300	1400	80.3	81.7	79.1	21
4/20/2006	1400	1500	81.3	82.3	80.5	19
4/20/2006	1500	1600	81.9	82.5	81.2	16
4/20/2006	1600	1700	82.6	83.4	81.4	15
4/20/2006	1700	1800	82.4	83.2	81.1	14
4/20/2006	1800	1900	80.9	82.4	78.9	15
4/20/2006	1900	2000	73.9	79.2	70.0	25
4/20/2006	2000	2100	68.5	70.1	67.5	38
4/20/2006	2100	2200	64.8	67.7	60.7	50
4/20/2006	2200	2300	59.6	63.1	56.0	63
4/20/2006	2300	000	55.2	57.0	53.3	76
4/20/2006	2359	059	55.4	56.2	54.9	80
4/21/2006	0100	200	56.7	58.3	54.0	79
4/21/2006	0200	300	54.2	57.9	52.1	83
4/21/2006	0300	400	52.3	53.3	51.0	84
4/21/2006	0400	500	49.9	52.2	47.6	86
4/21/2006	0500	600	51.5	55.0	47.0	84
4/21/2006	0600	700	55.1	56.0	54.2	72
4/21/2006	0700	800	55.1	56.0	54.4	77
4/21/2006	0800	900	57.1	58.3	55.8	79
4/21/2006	0900	1000	59.5	61.9	57.5	78
4/21/2006	1000	1100	60.8	62.4	59.5	76
4/21/2006	1100	1200	63.2	64.5	61.8	69
4/21/2006	1200	1300	63.8	65.0	63.0	66
4/21/2006	1300	1400	61.9	63.4	60.2	71
4/21/2006	1400	1500	59.4	60.8	58.5	77
4/21/2006	1500	1600	58.2	58.9	57.6	82
4/21/2006	1600	1700	57.3	58.2	56.6	84
4/21/2006	1700	1800	55.9	56.9	55.4	90
4/21/2006	1800	1900	55.5	56.0	55.0	89
4/21/2006	1900	2000	54.5	55.6	53.6	92
4/21/2006	2000	2100	53.3	53.9	52.7	95
4/21/2006	2100	2200	52.3	53.2	51.7	97
4/21/2006	2200	2300	51.9	52.2	51.5	97
4/21/2006	2300	000	52.1	52.5	51.7	96
4/21/2006	2359	059	52.1	52.5	51.7	98

APPENDIX C. SOIL MOISTURE

Date: 4/17/2006			
Times: 1000 through 1600			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Wooded Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Open Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Calibration Lanes	0 to 6	NA	3.4
	6 to 12	NA	18.6
	12 to 24	NA	19.4
	24 to 36	NA	21.4
	36 to 48	NA	18.7
Blind Grid/Moguls	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA

Date: 4/18/2006			
Times: 900 through 1400			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet Area	0 to 6	NA	13.7
	6 to 12	NA	32.6
	12 to 24	NA	30.7
	24 to 36	NA	22.7
	36 to 48	NA	43.8
Wooded Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Open Area	0 to 6	NA	2.1
	6 to 12	NA	11.3
	12 to 24	NA	12.1
	24 to 36	NA	15.8
	36 to 48	NA	16.7
Calibration Lanes	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Blind Grid/Moguls	0 to 6	3.2	NA
	6 to 12	14.3	NA
	12 to 24	15.5	NA
	24 to 36	12.6	NA
	36 to 48	18.7	NA

Date: 4/19/2006			
Times: 800 through 1500			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet Area	0 to 6	13.5	13.5
	6 to 12	32.8	32.7
	12 to 24	30.9	30.4
	24 to 36	22.9	22.6
	36 to 48	43.5	43.4
Wooded Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Open Area	0 to 6	2.0	1.9
	6 to 12	11.4	11.3
	12 to 24	12.0	12.3
	24 to 36	15.6	15.9
	36 to 48	16.5	16.4
Calibration Lanes	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Blind Grid/Moguls	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA

Date: 4/20/2006			
Times: 800 through 1500			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet Area	0 to 6	13.1	NA
	6 to 12	32.3	NA
	12 to 24	30.7	NA
	24 to 36	22.1	NA
	36 to 48	43.7	NA
Wooded Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Open Area	0 to 6	1.7	NA
	6 to 12	11.0	NA
	12 to 24	12.7	NA
	24 to 36	15.5	NA
	36 to 48	16.7	NA
Calibration Lanes	0 to 6	NA	3.4
	6 to 12	NA	18.6
	12 to 24	NA	19.4
	24 to 36	NA	21.4
	36 to 48	NA	18.7
Blind Grid/Moguls	0 to 6	NA	3.2
	6 to 12	NA	14.3
	12 to 24	NA	15.5
	24 to 36	NA	12.6
	36 to 48	NA	18.7

APPENDIX D. DAILY ACTIVITIES LOG

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Op Stat Code	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions
4/17/2006	2	CALIBRATION LANES	840	1440	360	1	INITIAL SETUP		GPS	NA	LINEAR	SUNNY MUDDY
4/17/2006	2	CALIBRATION LANES	1440	1515	35	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY MUDDY
4/17/2006	2	CALIBRATION LANES	1515	1530	15	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DATA CHECK	GPS	NA	LINEAR	SUNNY MUDDY
4/17/2006	2	CALIBRATION LANES	1530	1620	50	3	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	NA	LINEAR	SUNNY MUDDY
4/18/2006	3	BLIND TEST GRID	750	1010	140	3	DAILY START, STOP	EQUIPMENT SETUP	GPS	NA	LINEAR	SUNNY MUDDY
4/18/2006	3	BLIND TEST GRID	1010	1115	65	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY MUDDY
4/18/2006	3	OPEN FIELD	1115	1135	20	3	DAILY START, STOP	EQUIPMENT SETUP	GPS	NA	LINEAR	SUNNY MUDDY
4/18/2006	3	OPEN FIELD	1135	1220	45	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY MUDDY
4/18/2006	3	OPEN FIELD	1220	1245	25	5	BREAK/LUNCH		GPS	NA	LINEAR	SUNNY MUDDY
4/18/2006	3	OPEN FIELD	1245	1350	65	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DATA CHECK, CHANGE TO MUD TIRES FOR WET AREA	GPS	NA	LINEAR	SUNNY MUDDY
4/18/2006	3	OPEN FIELD	1350	1525	95	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY MUDDY
4/18/2006	3	OPEN FIELD	1525	1540	15	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	EQUIPMENT CHECK	GPS	NA	LINEAR	SUNNY MUDDY
4/18/2006	3	OPEN FIELD	1540	1605	25	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY MUDDY
4/18/2006	3	OPEN FIELD	1605	1635	30	3	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	NA	LINEAR	SUNNY MUDDY
04/19/2006	3	OPEN FIELD	745	925	100	3	DAILY START, STOP	EQUIPMENT SETUP	GPS	NA	LINEAR	SUNNY MUDDY

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Op Stat Code	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions
04/19/2006	3	OPEN FIELD	925	1225	180	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY MUDDY
04/19/2006	3	OPEN FIELD	1225	1240	15	5	BREAK/LUNCH		GPS	NA	LINEAR	SUNNY MUDDY
04/19/2006	3	OPEN FIELD	1240	1315	35	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DATA CHECK	GPS	NA	LINEAR	SUNNY MUDDY
04/19/2006	3	OPEN FIELD	1315	1600	165	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY MUDDY
04/19/2006	3	OPEN FIELD	1600	1655	55	3	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	NA	LINEAR	SUNNY MUDDY
04/21/2006	3	OPEN FIELD	745	1020	155	10	DEMOBILIZATION		GPS	NA	LINEAR	SUNNY MUDDY

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

APPENDIX E. REFERENCES

1. Standardized UXO Technology Demonstration Site Handbook, DTC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

4. Yuma Proving Ground Soil Survey Report, May 2003.

APPENDIX F. ABBREVIATIONS

ADST	=	Aberdeen Data Services Team
APG	=	Aberdeen Proving Ground
ATC	=	U.S. Army Aberdeen Test Center
ATSS	=	Aberdeen Test and Support Services
CEHNC	=	Corps of Engineers - Huntsville Center
DMM	=	discarded Military munitions
EM	=	electromagnetic
EMI	=	electromagnetic interference
ERDC	=	U.S. Army Corps of Engineers Engineering Research and Development Center
ESTCP	=	Environmental Security Technology Certification Program
EQT	=	Army Environmental Quality Technology Program
GPS	=	Global Positioning System
HEAT	=	high explosive anti-tank
JPG	=	Jefferson Proving Ground
MAG	=	magnetometer
MEC	=	munitions and explosives of concern
METDC	=	Military Environmental Technology Demonstration Center
POC	=	point of contact
QA	=	quality assurance
QC	=	quality control
ROC	=	receiver-operating characteristic
RTK	=	real time kinematic
SERDP	=	Strategic Environmental Research and Development Program
USAEC	=	U.S. Army Environmental Center
UXO	=	unexploded ordnance
VSEMS	=	vehicular simultaneous EMI and magnetometer system
YPG	=	U.S. Army Yuma Proving Ground

APPENDIX G. DISTRIBUTION LIST

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